

## **Medical Splinter Group Issues to Discuss**

### **Overarching Questions for the entire team to consider and derive integrated recommendations:**

- 1) What is the operational concept for lunar dust management?  
Within that Ops concept- What can be done to limit the risk of exposure that will adversely affect the crew's health?
- 2) What potential medical/health hazards of lunar dust do we need to mitigate, to ensure the safety of astronauts and to establish appropriate med ops capabilities and procedures?

### **Specific Questions:**

#### **A. What is the full range of routes/anatomical sites of dust exposure that we need to be concerned about?**

1. Pulmonary exposure
2. Major airway exposure
3. Oropharyngeal exposure
4. Nasopharyngeal exposure
5. GI tract
6. Skin
  - a. site-specific susceptibility
  - b. direct penetration vs. entry through epidermal appendages (sweat glands, hair follicles)
7. Ocular exposure
  - a. Cornea
  - b. Lid and lid margin
  - c. Conjunctiva
8. Other sites?

#### **B. What characteristics/properties of lunar dust make it a hazard to crewmember health?**

1. Size (distribution)
2. Shape (Surface area)
3. Surface properties
4. Angularity

5. Reactivity/ Unsatisfied surface bonds (delayed passivation)
6. Chemical composition/ toxin content (e.g. heavy metals)
7. Electrostatic
8. Magnetic

C. What is the full range of possible medical, physiological and pathological processes/ responses that we need to consider as a consequence of lunar dust exposure?

1. Pulmonary
  - a. Cough, from airway irritation
  - b. Excess mucous production, from airway irritation
  - c. Tearing from ocular irritation
  - d. Impairment of gas exchange
  - e. Airway reactivity (asthma-like process)
  - f. Airway edema, alveolar edema
  - g. Airway hemorrhage, alveolar hemorrhage
  - h. Impairment of gas exchange (acute versus chronic)
  - i. Fibrosis (sub-acute, chronic)
2. Skin
  - a. Irritation
  - b. Sensitization
  - c. Skin abrasion (especially in context of EVA operations, space suit)
  - d. Systemic penetration
3. Eye
  - a. Corneal abrasion
  - b. Corneal ulceration, scleral ulceration
  - c. Blockage of tear ducts?
  - d. Lid effects?
  - e. Conjunctivitis?
  - f. Systemic penetration
4. GI Tract
  - a. Irritation
  - b. Mucosal damage
5. Naso-pharynx?

## 6. Oro-pharynx?

D. Which medical/physiological processes are reversible? If reversible, what is the time course? Which processes are irreversible?

E. What operational scenarios need to be considered to provide a framework for envisioning lunar dust exposure to astronauts?

**Operational scenario #1:** Potential for crew member exposure to lunar dust will not be constant, and will be affected by both:

- 1) crew member activities (e.g. EVA tasks) and
- 2) the performance of advance life support systems (**nominal, degraded, contingency**) and other mechanical systems employed to limit crew member exposure to lunar dust.

Which activities have the highest likelihood of deleterious exposure and from which route?

Crew activities:

1. Crew member activities in the CEV
2. Crew member activities in a lunar lander
3. Crew member activities in a lunar habitat
4. Lunar surface exploration activities
  - Construction EVA
  - Maintenance EVA
  - ISRU deploy EVA
  - Power system EVA
  - Science EVA
5. Crew transfer from lunar surface into lunar habitat
6. Crew transfer from lunar surface into lunar access vehicle
7. Crew transfer from lunar access vehicle into CEV
8. Crew members activities during a contingency situation

**Operational Scenario #2:** Failure of life support systems, other mechanical malfunctions and un-anticipated operational scenarios may be more important determinants of crew member exposure to lunar dust than nominal scenarios. Dust control systems (e.g. HVAC-filters; electrostatic removal; magnetic capture, etc. ) state:

- 1.) Nominal
- 2.) Degraded

### 3.) Contingency

Which failure modes pose the greatest hazard?

1. Gradual deterioration of advance life support systems air filtration capabilities resulting in chronic “above spec” inhalation exposure
2. Acute failure of air filtration systems
3. Command shut-down of air purification systems in a power-limitation situation.
4. Exposure of crew members to dense “clouds” or “plumes” of lunar dust from un-anticipated operational scenarios.
  - a. Aboard CEV
  - b. Aboard Lunar Lander
  - c. In Lunar Habitat
5. Acute entry of lunar dust into the space suit (space suit breach)
6. Other modes of lunar dust exposure?

F. What are the “**expected**” modes/sites of crew member exposure to lunar dust, given the nominal operational scenarios envisioned?

1. Airborne lunar dust/inhalation exposure
2. Airborne lunar dust/GI tract exposure
3. Airborne lunar dust/skin exposure
4. Airborne lunar dust, regolith particles/eye exposure
5. Dust entry into the space suit/skin exposure
6. Dust entry into the space suit/inhalation exposure
7. Dust entry into the space suit/eye exposure
8. Dust entry into the space suit/GI tract exposure

G. What do we need to consider in terms of “unexpected” modes of crew member exposure?

H. Can we anticipate that 1/6th gravity, radiation, and other special space environmental effects (possible reduced atmospheric pressure, reduced ppO<sub>2</sub>) may have an exacerbating/multiplicative health impact on the physiological/medical effects of lunar dust?

I. What simple techniques for crew member “clinical status evaluation” in response to lunar dust exposure are already available, and what advanced technologies might be needed?

- a. Pulse oximetry
- b. Peak flow meter to assess obstructive (asthmatic) response
- c. Blood and other body materials analysis
- d. Non-invasive imaging options

J. What countermeasures do we need to consider providing to remediate at least some of the effects of lunar dust exposure, both anticipated and un-anticipated?

K. What treatment of lunar dust-induced disease do we need to anticipate and test?

- a. Inhaled beta-agonists? Other bronchodilators?
- b. Inhaled steroids?
- c. Supplemental oxygen for acute pulmonary exposure?
- d. Topical steroids?
- e. Cutaneous hygiene methods—routine (strippable coatings, etc.)
- f. Eye wash? (Medical device development needed?)
- g. Ocular steroids or other ophthalmic preparations?
- h. Decontamination methods—for unusual exposures
- i. Other drugs
- j. Other agents

L. To what extent are the planned “classical” toxicology studies sufficient to define all of the potential medical/physiological impacts of lunar dust exposure?

*What supplemental studies need to be incorporated into the roster of work that is already slated to be tackled?*

*Where are the knowledge gaps that currently contribute to the uncertainties in lunar dust toxicity?*

*How are those gaps best filled with targeted research? [What research project(s) will fill the gap?]*

M. What is an appropriate research program for investigating the contribution of lunar 1/6 G and microgravity environments to lunar dust toxicity?

N. What custom/special supportive facilities/technologies/methods need to be developed in order to preserve, transport, and administer lunar dust research materials:

E.g.

- a. Special vials for transporting lunar activated lunar dust, to preserve “activated” state.
- b. Methods for reproducibly transferring an aliquot of a dust sample from a transport vial to an experimental system (without particle size bias).

**Hypothesis #1:** Native lunar dust and high-fidelity simulants will passivated during transport and delivery, reducing the relevance of any testing of this material.

- a. Lunar dust simulants
- b. Re-activated Apollo curated materials
- c. Lunar sample return materials

O. What safety procedures must be developed for handling lunar dust samples in analytical laboratories?

**Hypothesis #2:** Lunar dust and high-fidelity simulants are laboratory materials for which material safety data sheets and other safety protocols need to be developed in advance of handling in lunar and terrestrial laboratories.

- a. In Exploration lunar surface laboratories
- b. Terrestrial laboratories producing passivated and activated simulants and curated sample
- c. Terrestrial sample receiving laboratories containing returned lunar dust samples

P. What is the appropriate panel of mineral particulate control materials to be used for research into the toxicity of lunar dust?

**Hypothesis #3:** Toxicity of lunar dust can only be understood in the context of the known terrestrial mineral particulate toxicology.

- a. Silica
- b. Volcanic dust
- c. Industrial glass dust
- d.  $\text{TiO}_2$ , others?

Q. What are the dust risk interfaces between EVA suits and the human body?

**Hypothesis #4:** Risk of untoward cutaneous effects from lunar dust entry into the suit depends on body site-specific factors in combination with suit factors.

- a. Highest contact pressures
- b. Highest points of friction
- c. Likeliest points of dust entry
- d. Map against biological threshold of toxicity across the human body